

PB-214 978

METEOROLOGICAL RESEARCH IN AIR POLLUTION

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1965

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 214 978

METEOROLOGICAL RESEARCH



*in
Air
Pollution*

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
5285 Port Republic Road
Springfield, VA 22154

LIBRARY

Environmental Protection Agency
5555 Ridge Ave., Cincinnati, O. 45213

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Meteorological services are provided to the Division of Air Pollution by the U.S. Weather Bureau. A staff of meteorologists is assigned to the Division's Laboratory of Engineering and Physical Sciences at the Robert A. Taft Sanitary Engineering Center for research on the meteorological aspects of air pollution. In addition to the work of the Laboratory, U.S. Weather Bureau personnel monitor contracts sponsored by the Public Health Service, appraise other meteorological research in the field of air pollution, and provide consultation to states and communities through the Technical Assistance and Field Studies branches of the Division of Air Pollution.

Updated. Document



METEOROLOGICAL RESEARCH IN AIR POLLUTION

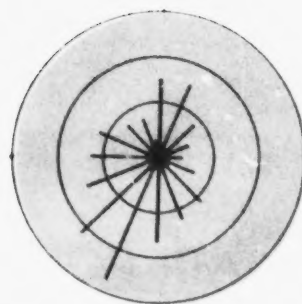
U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Air Pollution
Laboratory of Engineering
and Physical Sciences

Details of illustrations in
this document may be better
studied on microfiche

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

Foreword



Traditionally, meteorologists have been concerned with the elements that characterize our weather: temperature, humidity, visibility, atmospheric pressure, the direction and speed of winds, the kinds and amounts of cloud cover, and the several forms of precipitation. In forecasting, these elements are considered on a larger scale: the movements of air masses are plotted, high and low pressure systems are identified, and frontal lines are charted — for the predicting of future weather events. Climatology is a further extension of weather knowledge: the accumulation of detailed records and the study of over-all patterns throughout the years. Air pollution meteorologists deal with these same elements, but theirs is a highly specialized use of meteorological skills.

Systematic research in air pollution meteorology began over three decades ago in England, where the dispersal of chemical warfare agents into the atmosphere was at that time a military problem.

Since World War II the rapid growth of nuclear industries has activated new interest in air pollution diffusion studies — to cope with problems that arise when radioactive materials are released into the atmosphere. Such studies have been pursued for several years by government and private agencies.

But concern for environmental health is not restricted to such obvious hazards as chemical warfare and radioactive wastes. The over-all problem of community air pollution is immense, and it is increasing.

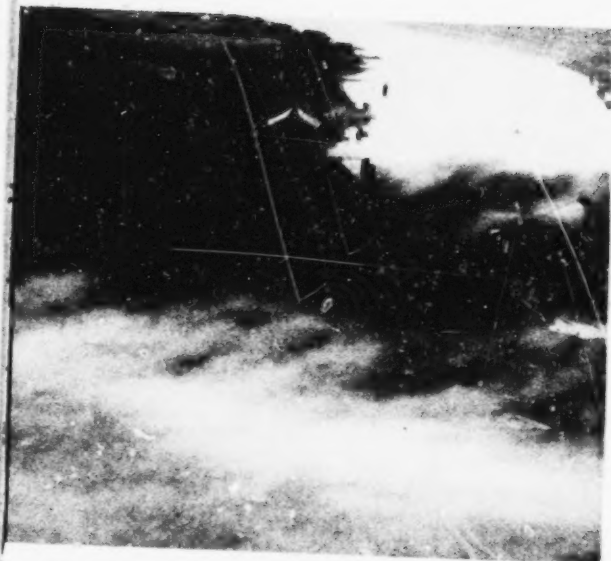
In both urban and rural areas, gases, vapors, dusts, and fumes are continually emitted into the air. They affect man's health and property. Air pollution research by the Public Health Service is directed to the serious problem of polluted community atmospheres. An important phase of this research is air pollution meteorology.





Weather patterns affect the intensity of air pollution in several ways:

- WINDS** - Wind direction determines where pollutants will go. Wind speed affects their dilution in the atmosphere; when wind speeds are high, an area is well ventilated and pollutants do not accumulate.
- TEMPERATURE** - Temperature often determines how much pollution is generated. Many kinds of pollution are heavier in winter when industrial, commercial, and domestic heating units are in operation.
- HUMIDITY** - Moisture content of the air determines how rapidly certain materials will deteriorate when they are in contact with polluting particles and gases.
- PRECIPITATION** - Various types of precipitation, such as rain, snow, and drizzle, serve as cleansing agents, removing pollutants from the air.
- CLOUD COVER** - Sunlight, which depends upon the type and amount of cloud cover, participates in the formation of photochemical smogs. Some of the chemical reactions that produce eye-watering irritants cannot take place without the energy provided by sunlight.



Combinations of these elements comprise weather patterns that can shape the course of an air pollution episode. The movement of weather systems and the characteristics of large air masses are determining factors.

Interestingly, the kind of weather that most often causes serious air pollution sometimes seems quite fine and fair. In autumn the days that follow the passage of a cold front are bright and pleasant, yet these are the periods during which harmful air pollution episodes most often start.

Sometimes when measured concentrations of pollutants are highest, the air seems relatively clean. Since many of the harmful gaseous compounds are invisible and odorless, we are not aware of their presence in the air. We readily discern the more annoying contaminants - the smokes and soots and odors. Although our senses tell us much about the nuisance value of air pollution, they are not reliable as an index of its seriousness.

The task of air pollution meteorologists is to identify and predict the many ways in which the weather affects the concentrations of airborne wastes. Some of the current projects in this research effort are described on the following pages.

Forecasting Air Pollution Potential

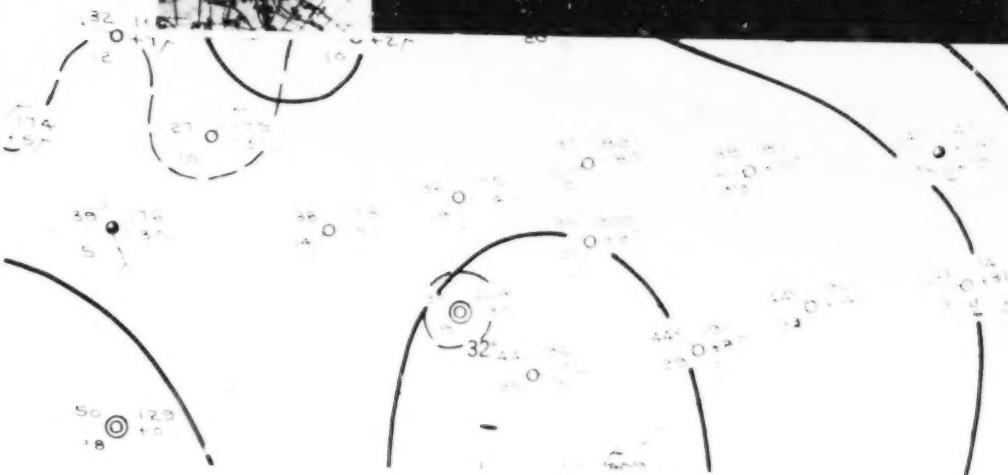
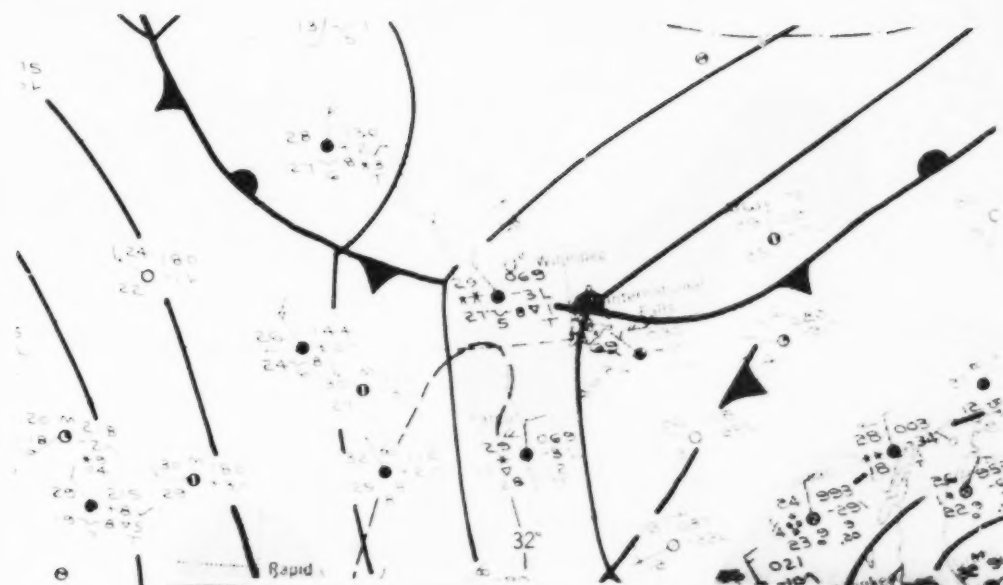
The potential for air pollution in a given area rises when an air mass stagnates. During periods of stagnation, pollutants emitted to the atmosphere are not dispersed. When stagnant air is overloaded with pollutants for a sustained period, we are in danger of an air pollution episode, a potential health and economic hazard.

If periods of high potential for air pollution can be predicted, the output of pollutants can be controlled in several ways, and very possibly a potential air pollution disaster can be stopped before it starts. The program of stagnation forecasts was designed for this purpose. In its first phase the forecasting program was applied experimentally to the eastern portion of the United States. More recently the operation has been expanded to include the states west of the Rockies.

Meteorologists have defined the basic pattern of stagnation in terms that enable them to detect the origin of a stagnating air mass and follow its development. Synoptic weather maps are closely monitored. When the criteria for possible stagnation are spotted and confirmed, an alert is transmitted by teletype on a special network. U.S. Weather Bureau officials in the crucial area then give notice that atmospheric conditions are conducive to pollutant accumulations. Governmental and industrial air pollution officials can then initiate special sampling to monitor the possible buildup of pollution, and, if warranted, plans may be made to curtail the activities that release pollutants to the air.

The basic forecast program is backed by climatological studies — review of weather records through the years to learn where and how often these stagnation periods have occurred. Studies show that, although they occur in all sectors and in all seasons, the southeastern United States is especially prone to air stagnation and September and October are the months in which it happens most often.

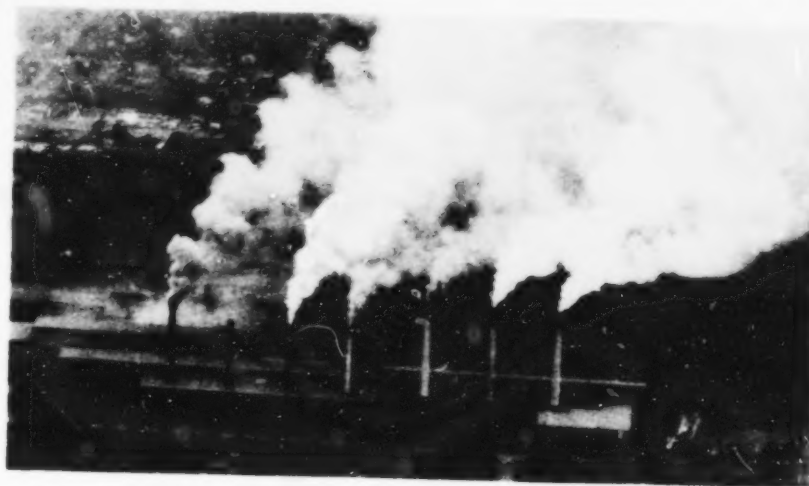
Now well past the experimental stage, the program of stagnation forecasts will continue: weather men are daily monitoring the nation's weather maps in search of air pollution trouble spots.



Dispersion Studies

When exhaust flows from an auto tailpipe, a concentrated stream of pollutant gases and particles strikes the air near street level. What happens to them then? How do the pollutants disperse into the air overhead? Or, when smoke leaves the stack of an industrial plant, how does the plume of contaminants mix with the atmosphere? How far are air pollutants carried?

The dispersion of pollutants into the air is complex, since sources of emissions vary greatly in pattern and effect: the plume from a single stack is a "point" source; emissions from a row of industrial stacks constitute a "line" source; the cluster of smoking chimney tops in an urban residential neighborhood presents an "area" source. How pollutants disperse from these various sources and where they are deposited determine what effects they will produce.



A line source



An area source

Diffusion patterns are formulated in terms of mathematical models, which can be used to predict the expected concentrations of pollutants in a given area. In a recent diffusion study, monthly wind data were used with such a model to calculate average pollutant concentrations over a monthly period. In another extensive study, the expected concentrations were computed for 24-hour periods. Results from these studies give promise that the expected concentrations of pollutants in a selected area can be estimated satisfactorily. The ability of meteorologists to provide such estimates is a significant aid to pollution control in urban-industrial communities and to the planning of future urban development.

The atmosphere around us is an unwieldy experimental tool. It cannot be controlled, nor can it be made to repeat its actions for comparative studies. The wind tunnel, therefore, has become a useful device for simulating the patterns of atmospheric behavior. By use of small-scale models of emission sources, model receptors, and controllable "winds," some air pollution problems can be simulated for detailed dispersion studies under laboratory conditions.

Dispersion studies are increasingly valuable in urban community planning. In selecting proposed industrial sites, for example, we can now be guided by meteorological facts. In several pilot studies, actual weather data from urban areas have been correlated with calculations based on known and proposed emission sources, charted as "source-districts" for computation. Clean air for tomorrow's cities depends greatly upon intelligent use of air pollution dispersion studies to guide community planning.

Air Pollution Climatology

Finding the relationships between air quality and weather elements requires an abundance of measurements and records. If civic officials recognize an air pollution problem, a community may undertake a thorough, city-wide air pollution study. During such a study, the air is sampled extensively. Special meteorological measurements are made simultaneously. At the end of the study, the pollutant measurements, the meteorological data, and past weather records for the area are analyzed and correlated. The result is an air pollution climatology: a series of typical weather and pollution patterns for the community.

Studies in Detroit, Louisville, and Nashville have shown that a very rough air pollution index for urban areas can be derived from a few important weather elements: the direction and speed of winds, the temperature of the air, and the vertical differences in air temperature (thermal stratification). A climatology of thermal stratification for Louisville was compiled from an extended series of temperature measurements at various heights on a downtown television tower.

The vertical temperature profile is important in air pollution studies, since vertical differences in temperature determine the ability of the atmosphere to disperse pollutants upward and thus distribute them throughout a greater volume of air. The concern with vertical temperature differences can be understood from the point of view of the scientist who hopes to evaluate the effects upon human beings of pollutants from a specific source. To calculate these effects, he must know where the person is located with respect to the source. The "where" is complicated not only by distance in miles along the earth's surface, but also by location in the vertical dimension.

Generalized airflow patterns are being developed for major urban areas of the United States. The dominant paths of airflow over a community are determined by many factors: shape of the surrounding terrain; proximity to bodies of water, mountains, or other outstanding topographic features; extent of the built-up area within the community. Typical patterns have been determined for such widely differing urban environments as Berlin, New Hampshire, and Los Angeles, California. As these studies progress, the airflow patterns for specific locations under a variety of weather conditions become more distinct. These patterns will provide another guidepost for prediction and control.

The structure of the air along the coastal lines differs from that inland. In a detailed study of marine air structure along the California coast, meteorologists are using a variety of techniques: the tops of cloud layers are analyzed by means of time-lapse photography, and the intensity of television signals at San Diego is used for data on thermal inversions in Santa Barbara, some 200 miles distant. The investigations have disclosed that the marine air layer is composed of several distinct sublayers, in which air pollutants are often carried in different directions at different levels.

The thermal inversion is characteristic of almost all severe air pollution episodes. In studying the frequency of such inversions throughout the United States, weather scientists are summarizing data obtained from radiosonde observations, in which soundings are made with electronically instrumented balloons. Thus they are amassing a history of thermal inversions, a useful basis for future air pollution studies.



Effects of a thermal inversion. The air at the surface is cooler than the air aloft. The layer of warm air overhead forms a "lid" that prevents pollutants from mixing upward.

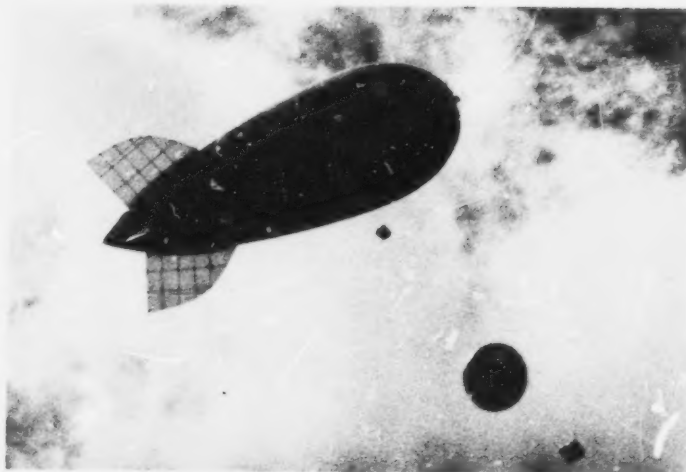
New Techniques In Observation and Sampling

Field studies of air pollution are relatively low-budget operations; they require the use of simple and economical but nevertheless effective techniques. In working with measurement problems, air pollution meteorologists are developing low-cost versions of more expensive commercial instruments and devising a variety of new techniques for exploration of the air.

Tracking a mass of contaminants from the time of emission through its trajectory in the atmosphere involves periods of time that range from hours to days. Some pollutant-tracking runs are made by releasing tracer material into effluent from the stack or roof of a known pollution source.

Air samples are collected throughout a dense network of stations while the tracer is being released at a uniform rate. From the amount of tracer collected by each sampler in the network, a dispersion pattern can be developed. Radar detection also is used to provide an hour-to-hour history of a specific pollutant mass. Successful preliminary radar-tracking flights have been performed with constant-volume balloons, which travel more or less at a predetermined altitude and are highly responsive to air motions.



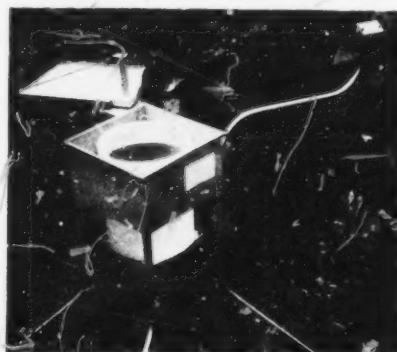


Balloons are used also to study in detail the vertical distribution of pollutants in the first 1000 feet of urban community atmospheres. Whereas the radiosonde observations performed routinely at many Weather Bureau stations provide only one sounding for each 500 feet of vertical ascent, the controlled ascent of tethered balloons, equipped for temperature and humidity readings and simple pollutant measurements, can give 20 readings in 500 feet — a much more detailed probing of the air pollution envelope.

Since the helicopter can perform vertical ascents and hover at designated heights, it is a made-to-order vehicle for measurements in the vertical dimension. Helicopter observations are particularly effective for measuring pollution added to an air mass by urban activities. An ascent made in the heart of an industrial center can be followed in a matter of minutes by an ascent under similar conditions in the relatively clean air of a suburban area upwind; in this way the background levels of pollutants in the air before it reaches the city can be determined.

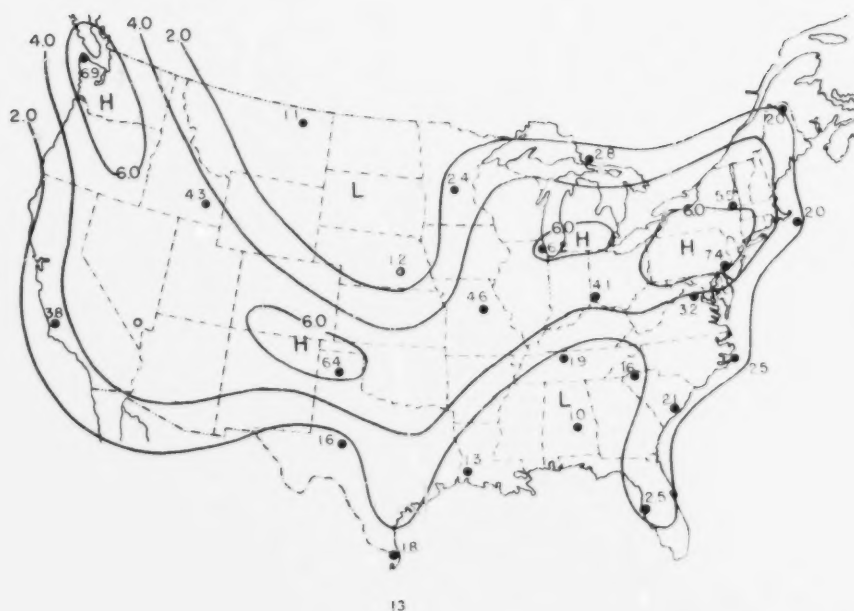
A strikingly simple and low-cost device for indexing air pollutant levels is the sun photometer, used to measure turbidity — the darkening or obscuring property of the atmosphere. The photometer, about the size of a box of kitchen matches, is exposed directly toward the sun and determines the intensity of the sunlight. Since pollutants in the atmosphere diminish the intensity of light between the sun and observer, the photometer provides a rapid and sensitive indication of the total pollutants in the air. An informal Turbidity Network of observing sites has been established throughout the United States. Preliminary data show that the rough index of over-all air pollution provided by the simple sun photometer compares well with the concentrations measured by more elaborate devices.

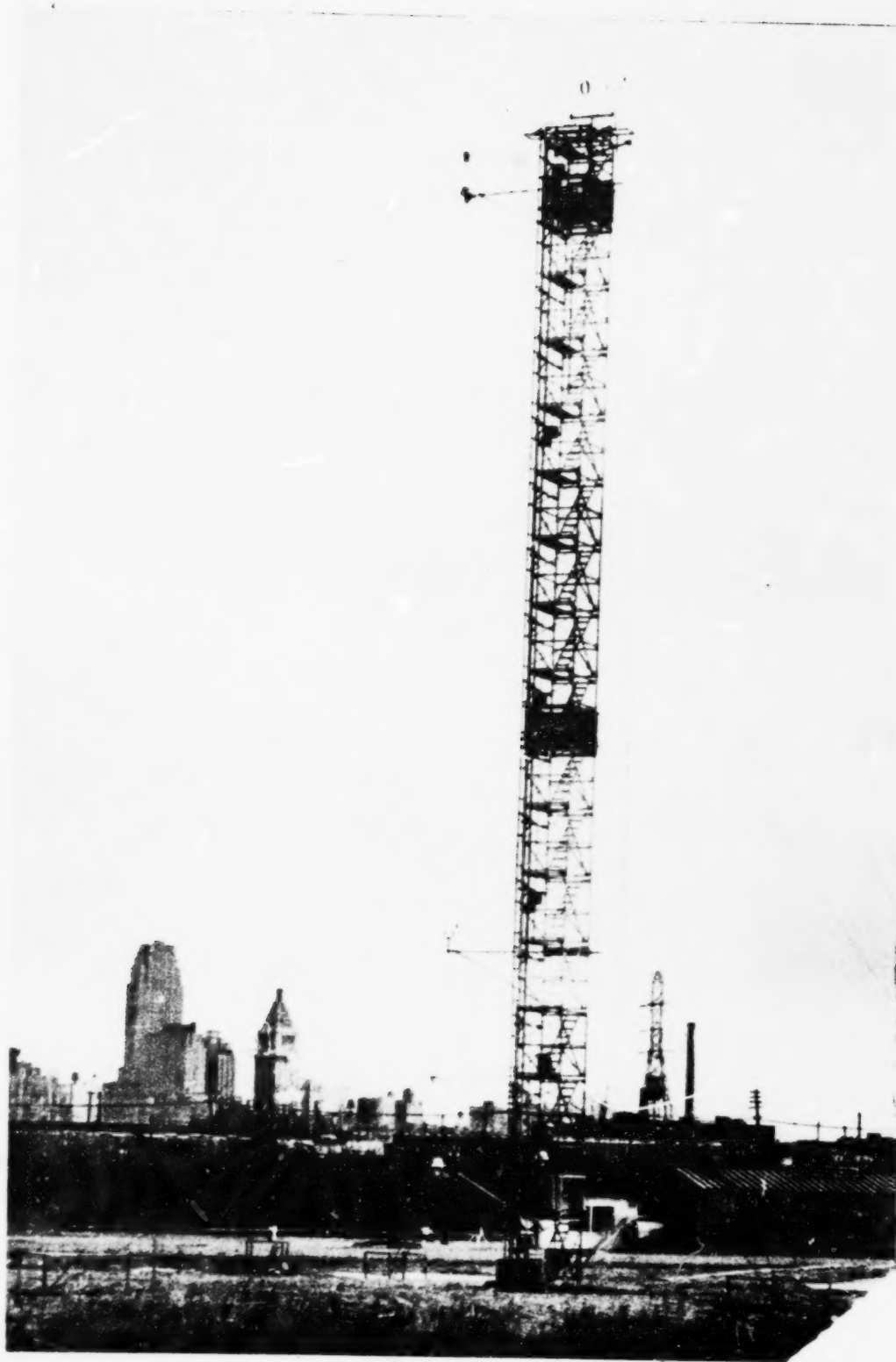
The chemistry of precipitation, too, is a guide to the type, amounts, and distribution of pollutants in the air. Rain and snowfall have a cleansing action as they sweep pollutants from the atmosphere. The interplay between pollutants and precipitation is studied in a Precipitation Chemistry Network of about 30 stations in the United States. Precipitation samples are collected in receptacles especially designed to open only during periods of precipitation. Thus the samples contain only the pollutants carried by precipitation and do not include ordinary dustfall. Samples from the network are shipped monthly to the Sanitary Engineering Center for chemical analysis and radioactivity count.



Precipitation sampler

Average sulfate concentration in precipitation, 1960 (milligrams per liter)



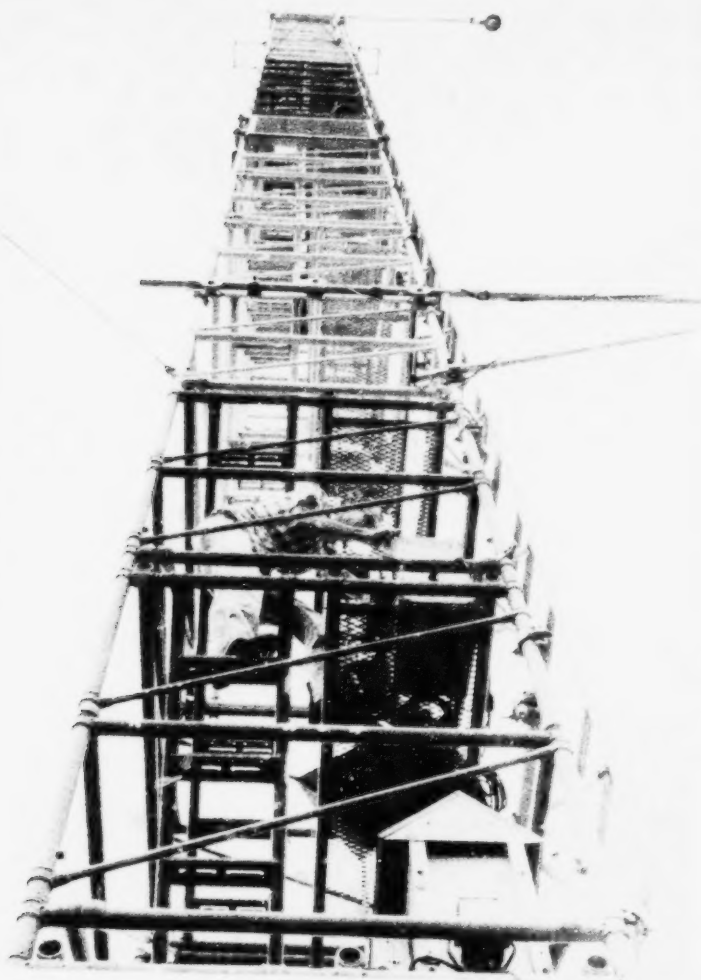


Gest Street Experimental Facility

Supporting work for many of the air pollution weather studies is performed at the Gest Street Experimental Facility (GSEF) in Cincinnati. The Facility is located in an urban-industrial complex about 15 blocks from the heart of the downtown district. It is situated on the floor of Cincinnati's broad 'basin' area, a flat glacial bed that extends roughly northward from the Ohio River. This flat pathway, the Millcreek Valley, is heavily industrialized along its entire course.

The facility is located within 2 miles of the Cincinnati Continuous Air Monitoring Station,* where continuous records of air pollutant concentrations are obtained by means of automated instruments and data-processing techniques. The results of GSEF observations are correlated in detail with these continuous records of contaminant levels in the downtown area.

* A brochure describing the Continuous Air Monitoring Program of the Public Health Service is available upon request from the Air Quality Section, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati, Ohio.



Observations at the Fairbury station are of special interest in air pollution studies: vertical and horizontal wind directions and vertical temperature differences, both obtained from an instrumental 100-foot weather tower. The tower is also equipped with air sampling devices at several levels.

A transmissometer provides data for studies of visibility and other light-transmitting characteristics of the atmosphere. At a level 10 feet above the ground a beam of light of constant intensity is directed from a photoradiometer receptor 750 feet away. Interfering pollutants in the atmosphere reduce the intensity of the beam at the receptor, where the degree of interference is translated into visibility readings in fractions of a mile.

Future Trends

IN RESEARCH

Future meteorological studies will be fitted to meet the long-range as well as the immediate needs of air pollution research. Such projects will include:

- Intensified studies of diffusion processes, especially as they apply to the movements of pollutants within cities and between major urban complexes.
- Studies of pollutant effects on the physical properties of the atmosphere. For example, how do pollutants affect the electrical characteristics of the atmosphere, or its ability to transmit light?
- Stagnation forecasts for specific local areas. Present techniques will be scaled for more localized conditions, with maximum use of mathematical diffusion models for air movement over specific urban-industrial sites.

IN APPLICATIONS

The practical uses of the weather research described in this booklet take many forms. Although air pollution meteorology is a young science, progress to date already has aided in the fight for cleaner air. Weather research is used in

- detecting sources of air pollution
- evaluating the intensity and scope of specific pollution incidents
- estimating allowable emission rates from given sources



COMMUNITY PLANNING

As our cities grow, sometimes joining borders to form a multi-city complex, or "megapolis," the need for community planning and urban redevelopment is more urgent. Air pollution weather research will significantly aid city planners, architects, and engineers in working out effective land-use programs; rapidly expanding industrial, commercial, and residential areas can be integrated in an overall community plan. It is hoped that considerations of air quality and environmental health will rank with the social and economic factors that dictate how our cities grow.

With continuing research and experimental application, meteorologists are learning to understand the complex weather factors that affect the behavior of pollutants. Through these studies, they are establishing patterns to guide in urban planning and to protect the air quality of our nation's expanding communities.